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ECONOMIC COMMISSION FOR ASIA AND THE FAR EAST

CAMBODIA, LAOS, THAILAND AND VIET-NAM

Committee for Co-ordination of Investigations
of the Lower Mekong Basin

French Sedimentation Mission
on the Great Lake in Cambodia

CONSIDERATIONS ON THE UTILIZATION OF RADIOISOTOPES FOR THE STUDY OF SEDIMENT TRANSPORT

by J.P. Carbonnel, Sedimentologist

CONSIDERATIONS OF THE UTILIZATION OF RADIOISOTOPES FOR THE STUDY OF SEDIMENT TRANSPORT

By J.P. Carbonnel,
Sedimentologist

In 1960, the International Atomic Energy Agency sent out an expert mission to study the possible applications of radioactive isotopes in studies of the Lower Mekong Basin. The report (A.I.E.A. - RI/10) by Mr. Eriksson and Mr. Hours was the result of that investigation. The authors of the report specially emphasize two possible utilizations of radioisotopes in this field: tracer methods for water discharge measurement and tracer methods for bed load transport. Concerning the latter, they consider two methods according to the type of sand transport and river regime, namely, the pulse method and the integration method. In this note, we shall not repeat their considerations on these methods.

In document WRD/MKG/INF/L.85, dated 16 February 1962, IAEA suggested a draft plan for radioactive tracing of bed load in the River Stung Sen in Cambodia. This programme, which is divided in two phases, appears to satisfy the necessary conditions of the envisaged method. It is a sensible programme. However, it might be useful for us to bring certain points into clearer focus and report on our present knowledge of conditions of sedimentation and bed load transport in the River Stung Sen.

DESCRIPTION OF THE PROBLEM

The final result of investigations should be to construct a discharge bed load transport graph. For a substance of a particular grain such a curve will show a specific point of origin corresponding to the threshold of movement of the substance in question. This threshold varies with the discharge, i.e. the flow velocity, whether increasing or decreasing (rising or subsiding flood).

/ Therefore,

Therefore, it may be seen that this is a very complex problem, which involving several more or less well defined parameters:

(1) It is necessary to have a good knowledge of the hydrologic conditions of the river in order to forecast discharges at the beginning and during the experiment and thus to regulate the conditions of the experiment, in particular as concerns the size of the radioactive substance to be used. This knowledge is fundamental, because any error in computation of the size of the grains entails the risk of contaminating the site of the experiment with too large radioactive elements which will not "take of", or will too small elements which will be lost between the time of introduction in the stream and the time of the first measurement.

Now, the discharge hydrographs of the Stung Sen are very imperfectly known and if it may be expected that they will be better known in one year's time, in any case it will be at one point only, i.e. at Kompong Thom.

(2) The obverse problem is as follows: knowing the discharges, what is the size of the transported grains? This problem has been solved theoretically in the laboratory, but on the field the geomorphologic conditions, and also the conditions of the former deposits (mixture of variously-sized fractions, compaction), may modify the results obtained in the laboratory. Hence, it is necessary to investigate the sandy formations of the river before attempting any experiment with radioactive particles. We deliberately use the term "experiment", because it is useful to recall that the utilisation of radioisotopes in this field is still in the experimental stage.

However, it may well be that this method will be the method of the future in this field, for which no perfectly accurate method has been developed to-date.

/ OBSERVATIONS

OBSERVATIONS

We have been able to make some observations on the flow of the Stung Sen and those observations show how necessary it is to undertake, as an indispensable preliminary condition, a detailed survey of the sedimentation regime of that river.

In particular, we observed a difference in the sedimentation process, hence in transport, of the sands of the Stung Sen between Kompong Thom and the mouth of the river. At Kompong Thom the bed of the river is formed by dunes, whereas at Kompong Chamlang, where we have taken samples, the bed presents the aspect of a clay depression with a central channel, often narrow, composed of sand. In the channel, the sand appears to "flow" as a river within the river.

Shallow soundings have enabled us to realize how the process of sand transport works. We give in appendix to this note two sections of the Stung Sen, in each of which we have effected three soundings. These soundings can easily be interpreted:

- In the centre of the Stung there is a large mass of sand, generally from medium to fine, in rare cases very fine, with a comparatively homogeneous grain.

- On the flanks of the Stung, alternating layers of sand (generally very fine) and clay, the latter usually containing very fine strata of organic debris, leaves lying flat according to stratification, twigs, etc.

In consequence, the transport process can be envisaged as follows: there is a permanent sand channel in the axis of the Stung:

- In flood time, the sand starts moving and, according to the force of the transport agent, overflows from its permanent channel, with an intensity parallel to the intensity of the flood itself. Part of this sand then deposits on the sides of the river.

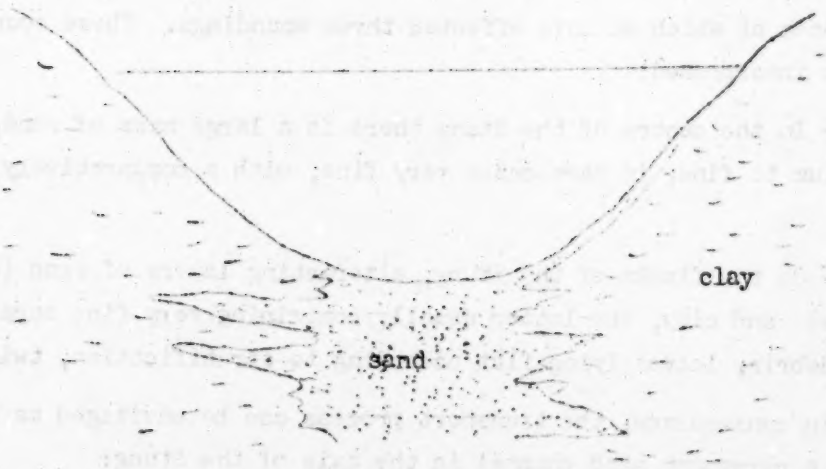
/ - During

- During the next dry season, a thin layer of clay deposits over the sand.

The process is renewed at the next flood, which sweeps away part of the previously deposited clays. It should however be noted that in any particular point of the river bed we do not necessarily find a regular alternation of sand and clay strata, because for the "flood sand" to reach that point, it is necessary for the flood to exceed a specific intensity, which is a function of the distance of that point from the permanent channel.

In cross-section, we have a more or less extensive penetration of sand layers between the clay layers.

The following figure gives an idea of such a cross-section.



/ In this

In this particular case, it is easy to understand the complexity of the problem. And this represents only one type of bed load transport; there is certainly another type of process in the vicinity of Kompong Thom, where the sand is displaced by moving dunes. The latter method of transport is necessarily less rapid than the one previously described: any study of bed load transport should take this difference into account.

Following the above general considerations, it may be useful to recall the somewhat pessimistic conclusions (but it is necessary to see things as they are) of Mr. J. Tricart:

"The method of radioactive tracers is difficult to apply in river due to the following factors:

(a) Security conditions which comple immersion of the isotopes in conditions which are often not very suitable from the geomorphogic point of view.

(b) The necessity of multiplying experiments with excessively costly equipment.

(c) Difficulty of identifying the marked substances after transport.

(d) The impossibility of renewing an experiment as long as the radioactivity of the previously immersed substance persists".

("Critical analysis of experimental radioactive methods in problems of river dynamics" by J. Tricart 1962).

The above conclusions and our own observations lead us to hope that before undertaking investigation of sand transport in the Stung Sen by means of radioactive tracers, the following conditions will be fulfilled:

(1) Full knowledge of hydrologic conditions.

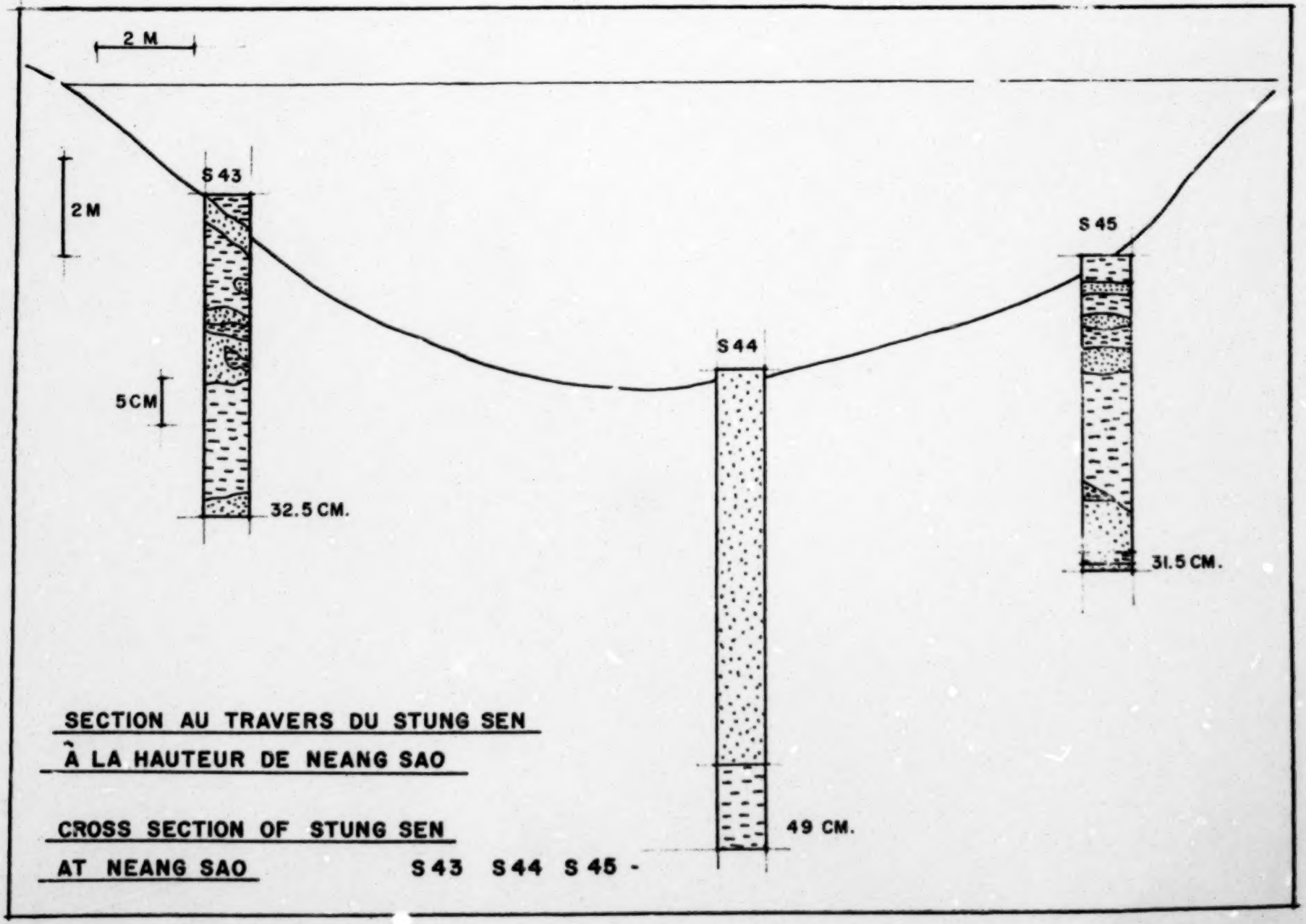
(2) The different types of formations of the Stung should be identified and mapped; a grain size study should be previously effected for each type.

/ (3)

(3) The team of sedimentation experts currently working in the field should be contacted and a cooperation programme should be organized.

Finally, we feel it would be very desirable that, simultaneously with this study, investigations based on other methods should be used to support it, in order to obtain satisfactory overall results (See the suggestions submitted in report WRD/MKG/INF/L.86, of 21 June 1962).

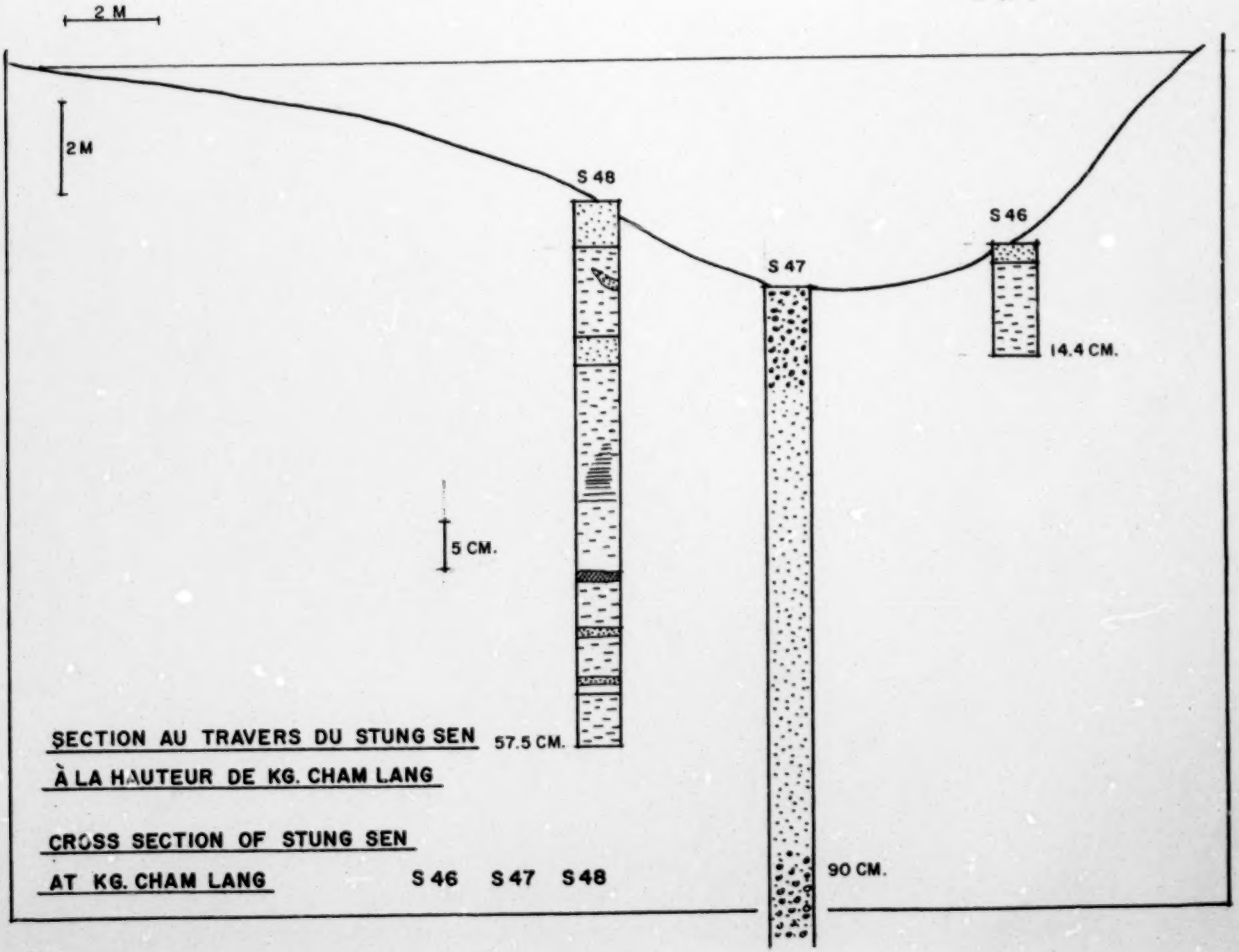
Phnom Penh, 26 August 1962



SECTION AU TRAVERS DU STUNG SEN
À LA HAUTEUR DE NEANG SAO

CROSS SECTION OF STUNG SEN
AT NEANG SAO

S 43 S 44 S 45 -



SECTION AU TRAVERS DU STUNG SEN
À LA HAUTEUR DE KG. CHAM LANG

CROSS SECTION OF STUNG SEN
AT KG. CHAM LANG

S 46 S 47 S 48

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ECONOMIC COMMISSION FOR ASIA AND THE FAR EAST

CAMBODIA, LAOS, THAILAND AND VIET-NAM

Committee for Coordination of Investigations
of the Lower Mekong Basin

TONLE SAP BARRAGE (MEKONG VALLEY)
PROJECT INVESTIGATIONS

Progress Report of the work done by the Indian Mekong Tonle Sap Team for the period ending September 1962

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TONLE-SAP BARRAGE (MEKONG VALLEY)

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1. INSPECTIONS

(a) Shri P.R. Ahuja, Chief Engineer, Central Water and Power Commission and the Project Manager for the Tonle Sap Project, inspected the progress of investigations in June 1962.

(b) Mr. Ammstrong of Burmah-Shell Film unit visited the Prek Kdam and Kompong Chhnang sites in June 1962.

(c) Mr. Kanwar Sain, the Acting Executive Agent of the Mekong Committee, Bangkok, visited Cambodia during August 24 to August 28 and again from August 31 to September 4 and held discussions with the Field Manager on various questions pertaining to the Tonle Sap investigations and also paid field visits to the Grand Lake, some of the Lake tributaries and the Tonle Sap river, both by land as well as by boat.

2. PERSONNEL

Mr. J.T. Karira, Research Officer of the Indian Team who arrived in Phnom Penh on May 2, left for New Delhi on July 31, 1962 for official consultations with headquarters.

3. EQUIPMENT FROM INDIA

Orders were placed for the procurement of practically all the drawing and mathematical instruments and most of the laboratory equipment and equipment for field investigations required to be sent from India. Orders for the drilling equipment and accessories have also been placed. A good part of the equipment has been since shipped and the first consignment of cases containing equipment for the proposed soil and concrete laboratory and field surveys etc. shipped from India has since been received at Phnom Penh and stored.

/4. EQUIPMENT

4. EQUIPMENT FROM NEW ZEALAND FUNDS

All the equipment ordered in January 1962 from Soil Test Inc. USA, Geophysical Specialities USA, and Messrs. Beckman USA, have been received. For all the items received, the material is carefully verified and a certificate of verification is endorsed on the firms' invoices which are then sent to the Mekong Committee Secretariat, Bangkok, through the UN Regional Representative, Phnom Penh, for arranging payment. The invoices for all items have been sent to Bangkok duly verified exception for the Bishop sand sampler supplied by Soil Test which will be verified in the near future.

No equipment has so far been received from Messrs. Leonard Farnell of England.

In response to a reference earlier made to the Executive Agent of the Mekong Committee for arranging procurement of additional equipment, worth $10,000 for the proposed soils and concrete laboratory, quotations were called for by him from 11 firms. Only 2 quoted for one item each, while 3 regretted their inability to submit the proposals. The remaining 6 firms did not give any reply. Particulars of a few more firms have since been furnished to the Executive Agent and further necessary action has been taken by him.

In consultation with and through the good offices of Mr. Van Riet of the Mekong Committee it was decided in the first fortnight of June, to place a firm order on Messrs. Pongsoviwat Ltd., Bangkok, for the supply of a 30' boat fitted with a Chevrolet gasoline engine. This order was however not placed because subsequent enquires revealed that they would not be in a position to deliver the boat in a reasonable time.

The Executive Agent also authorized the purchase of a small used aluminium boat fitted with outboard motor from the Certeza Surveying Co. But the inspection of the outboard motors showed that they were not in good condition and Certeza did not favour the sale of only the boat without the outboard. Hence this deal also did not go through. Efforts are continuing to obtain the boats and the motors.

/5. SUB-SURFACE

5. SUB SURFACE INVESTIGATIONS AT KOMPONG CHHNANG

A high priority was given to the work of sub-surface investigations at Kompong Chhnang in the period under review, because knowledge of the sub-surface conditions of the Tonle Sap river at Kompong Chhnang between the western hill of Phnom Krang Romeas and the eastern hill of Neang Kang Rey has an important bearing on the precise location of the proposed barrage. In this investigation, the following three methods have been adopted:

(i) Open test pit excavation to the extent possible
(ii) Use of engineering seismograph, and
(iii) Driving casing pipes and collecting samples at different sub-surface elevations by wash borings.

Open test pits could not be excavated deep enough, because of ground water conditions. In almost all the pits, sub-soil water was encountered within 3 metres below ground level and continued to flow in at such a rate that open pumping did not materially affect the position. However, the open excavation helped in exposing the top two or three layers, a knowledge of which proved very useful in the interpretation of the results by the other two methods.

The conclusions of the investigations done so far may be stated briefly as below:

On the west bank of the Tonle Sap slightly to the north of the Kompong Chhnang town at several places, a layer of decomposed laterite with concretions was encountered immediately below a thin layer of top soil. According to the nature of the samples of the over-burden collected above elevation -6.00, it did not appear likely that suitable hard rock would be met with above elevation -10.00 m.

On the east bank, the indications offered by a flew test pits and seismic traverses are that a thick layer of clay lies over a sub-surface layer of harder material, whose hardness appears to be increasing from the river towards the hill Neang Kang Rey.

/Further

Further explorations will be made to investigate the nature of sub-soil and foundation conditions at Kompong Chhnang.

6 (a) TOPOGRAPHIC SURVEY

Topographic survey was done at Kompong Chhnang consisting of laying out a tentative axis between Phnom Kong Romeas on the west bank and Nean Kang Rey on the east across the islands in the river and laying down two lines, one half a kilometre upstream and the other half a kilometre downstream. These axes served as the basis for the sub-surface investigations described above. A brief traverse was run connecting these axes with the traverse line established by the Certeza Surveying Company at the request of the Indian Team in May, 1961.

Levelling was done along the axis across the islands and on both banks connecting the base line established by the Certeza Surveying Company on the Kompong Chhnang-Pursat road in the vicinity of Phnom Krang Romeas to indicate the ground levels at sites selected for sub-surface investigations.

Also levelling was done between the Bench mark at the Post Office building in Kompong Chhnang town with the water level of the Tonle Sap at Kompong Chhnang port to serve as a check on the water level observations at Kompong Chhnang.

At Kompong Luong, upstream of the Prek Kdam ferry, three tentative axes were laid across the river, out of which one was selected as the axis for the proposed barrage at this place, connecting the road in the heart of Kompong Luong town on the west bank with Prek Kdam-Skoun road on the east.

Ground signals were established both at Kompong Chhnang and at Kompong Luong to facilitate sounding operations in the month of July to complete the cross-sections.

In cooperation with the personnel of the Cambodian Department of Navigation and the UN Special Fund Hydrographic Study team for the Mekong, soundings of the river bed across the selected axis were taken at Kompong Luong, slightly to the north of the Prek Kdam Ferry on July 12, 1962 and

/similar souding

similar soundings were taken in the various channels at Kompong Chhnang on July 13 and 14.

In order to provide the basis for a study of variations in the river bed levels along the full length of the river, a longitudinal profile of the river was taken from Phnom Penh to Snoc-Tru, a distance of about 140 km With the help of a boat and an echo-sounder taken temporarily for the purpose from the Port authories at Phnom Penh on September 14 and 15, 1962. A similar operation was done in December 1961 when the flow was from Snoc Tru to Phnom Penh,

During September, soundings were taken across the river at Kompong Tache, along a line connecting the Vat Taches on the west bank to the school in Phnom Phum Thmoll Krom on the East bank.

Levelling is being done on the land area to the west of Kompong Taches and soundings are being taken to the east of Phum Thmoll Krom.

6 (b) TOPOGRAPHIC MAPPING

Discussions were held by the Project Manager, Shri P.R. Ahuja, at Phnom Penh on 7 June 1962 in the office of the Director of the Service Géographique Khmer, with the representatives of the S.G.K., the USA Army Map Service, the Certeza Company and the Mekong Committee on the mapping requirements for Tonle Sap investigations.

It was understood that the ground control computations by the US Army Map Service for the Kompong Chhnang area would be completed by 1st September, 1962 whereafter the preparation of topo maps to the scale of 1 in 10,000 would take another 2 months by the SGK so that topo maps at Kompong Chhnang would become available by the end of November.

In the meantime, Certeza promised to complete their ground control by end of June and furnish the data at Kompong Chhnang to the Indian team (since received).

/In so far

In so far as Prek Kdam area is concerned, for which ground control was already obtained by S.G.K. from USAMSFE, Tokyo, the S.G.K. informed that they have already commenced their work on the preparation of the map and hoped it would be completed by end of June (since received).

During the period under review, continuous consultations were kept up by the field staff with S.G.K., USAMSFE and Certeza Company on matters relating to topographic survey and mapping.

A plan of the area at Prek Kdam to the scale of 1 in 10,000 with contour intervals of 5 m was prepared by the S.G.K. and transmitted to us. The field work done at Kompong Luong and the results of the soundings were plotted on this map.

Similarly a cross-section of the Tonle Sap at Kompong Chhnang was prepared on the basis of surveys between Phnom Krang Romeas and Phnom Neang Kangrey.

Ground control data along the traverse and level lines run by Certeza Company in response to the request of the Indian Team in May 1961 was collected from them. This data includes the data from Phnom Neang Kangrey up to Barai on the Siemreap road on the east.

Thus the cross-section prepared between Phnom Krang Romeas and Phnom Neang Kangrey together with the data supplied by Certeza between Neang Kangrey and Barai provide a complete cross-section of the Tonle Sap at Kompong Chhnang extending from road to road.

On the basis of information readily available with the Cambodian Ministry of Public Works, Roads Department, a site survey was prepared for the area in the vicinity of the bridge at km 54 on Prek Kdam-Skoun Road through which passes a considerable quantity of the Mekong back spill into the Tonle Sap. This site survey is only tentative as it is derived from available records. A more detailed field survey will be done in the next working season, if the Prek Kdam site is finally selected.

/The data

The data referred to above is under examination in the design unit of CWPC at New Delhi.

7. SELECTION OF SITE FOR THE LOCATION OF THE BARRAGE

Apart from the field investigations, being conducted by the Indian team necessary for the preparation of designs and cost estimates in the first stage, a number of collateral investigations by other agencies and participating programmes were outlined in Appendix F of the Plan of Operations as being essential to be made available to the Indian team for the preparation of comprehensive project report. The requirements of collateral investigations were reviewed in detail by Shri P.R. Ahuja, the Project Manager, during his visit to Cambodia in the first week of June 1962 with the representatives of various other interested agencies like the Mekong Committee, Departments of the Royal Cambodian Government, UNTAB, and French teams for delta model, fisheries, sedimentation and hydrology.

So far only two sites have been under investigation, one at Kompong Chhnang and the other at Prek Kdam. However, during his last inspection visit (July-August), the Acting Executive Agent of the Mekong Committee, Mr. Kanwar Sain, suggested that investigations be made of a third site in between Prek Kdam and Kompong Chhnang. This would extend from Kompong Taches on the west bank, passing through Phnom Thmoll Krom on the East Bank, to Pa Av on the Skoun Road. Area maps to the scale of 1 in 100,000 show the locations of these places. Accordingly a high priority is being given now to the field work at Kompong Taches for the preparation of a draft report on the choice of site. The fact that the river level is now high and rains are frequent, presents some problems in the type of work that has to be done at Kompong Taches, but every effort is being made to complete the operations as early as possible in spite of rains.

8. TONLE SAP FISHERIES

The problem of the Tonle Sap barrage vis-a-vis the Tonle Sap fisheries was discussed in detail by the Project Manager during his June visit to Cambodia

/with the

with the representatives of the Royal Cambodian Government and the French Fisheries Mission. Based on these discussions, a report has been prepared on various aspects concerning the development of Fisheries and the proposed barrage on Tonle Sap. This report was based on a number of personal discussions on various facts of the problem with the Cambodian Department of Fisheries and the personnel of the French Fisheries Mission by the Project Manager and the Field Manager. The report has recently been forwarded to the Mekong Committee secretariat in Bangkok for their information and necessary action.

9. DATA COLLECTED FROM OTHER AGENCIES

Hydrological data on Purset, Mongkol Borey and Siemreap tributaries has already been collected from USAID.

Similarly data in respect of the Battambang tributary has already been collected from the SOGREAH.

Messrs. Harza International Co. have transferred all their operational responsibilities and the data to the Cambodian Government from May 1, 1962. Hydrological data from the Cambodian Government authorities is now being collected.

With respect to the data collection from Viet-Nam a letter has been received from the Saigon authorities suggesting that a personal visit to Saigon will help to sift out what exactly is needed by the Indian team.

Hydrological data available with the Cambodian Ministry of Public Works, is being collected in so far as the Tonle Sap at Kompong Luong des Lacs, Snoc Tru, Kompong Chhnang, Kompong Taches, Stung Sen, Phnom Penh Port is concerned. After this is completed, data for the Mekong proper in Cambodia will be collected.

It is gathered that Harza International have submitted to the Mekong Committee their final report along with data volumes. The Mekong Committee is being requested to make two copies of this available to us. This data would constitute the reliable basis for design and would cover not only all the data collected by Harza themselves but also some historical data together with rating curves.

/In the meantime,

In the meantime, meteorologic data from the Cambodian service of Meteorology is being collected.

10. OFFICE AND LABORATORY ACCOMMODATION

The Cambodian Government have placed two rooms in the Salle des Conférences at the disposal of the Indian team to serve as their office accommodation.

Discussions are continuing with the concerned Cambodian officials on suitable accommodation to set up the Soil and Concrete Laboratory. No final decision has as yet been taken. But in the meantime, the Cambodian Government have been kind enough to place at the disposal of the Indian team two rooms in the basement of the Salle des Conférences to keep the equipment already received.

Although two rooms are being occupied in the basement of the Salle des Conférences, these rooms are at present being used only for storing the equipment already received, in the absence of official authorization to set up the Laboratory in the basement. Informal enquiries made from Mr. Khiou Bonthonm, the Secretary Général of the Technical Commission of the Cambodian National Mekong Committee and Mr. Chann Pech, the counterpart Manager for the Indian Tonle Sap investigations reveal that the question of official authorization is now before the Prime Minister of Royal Cambodian Government. Efforts are being made to obtain this authorization through normal official channels as expeditiously as possible.

11. DESIGN UNIT IN CWPC AT NEW DELHI

The Government of India have since sanctioned the required staff for the Design Unit in CWPC at New Delhi out of which some staff are already in position. The full complement of staff, shall be posted as soon as the complete data of the project becomes available.

On the basis of the data available so far the following drawings have been prepared:

/(i) Gauge

(i) Gauge and discharge hydrographs for Mekong at Phnom Penh and Tonle Sap at Prek Kdam sites.

(ii) Mass curves showing the inflow and outflow curves of Great Lake.

(iii) G & D curves of the main items (a) Mekong, above and below Phnom Penh and (b) Tonle Sap.

(iv) Tentative cross-section of the barrage (spillway portion) at Prek Kdam.

The studies of the hydraulic design of the barrage at Prek Kdam site are being finalized, while these of the barrage at Kompong Chhnang will be taken up shortly.

12. CENTRAL WATER AND POWER RESEARCH STATION, POONA

The estimate for the construction and operation of hydraulic models of Mekong river (including Great Lake) and barrage across Tonle Sap is being processed.

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ECONOMIC COMMISSION FOR ASIA AND THE FAR EAST

CAMBODIA, LAOS, THAILAND AND VIETNAM

Committee for Coordination of Investigations of
the Lower Mekong Basin

QUARTERLY REPORT

January - March 1962

of the French Mission for bauxite prospection in the Lower Mekong Basin

by Mr. H. Cruys
B.R.G.M. Expert Geologist, Chief of Mission

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QUARTERLY REPORT

January - March 1962

of the French Mission for bauxite prospection in the
Lower Mekong Basin

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by Mr. H. Cruys
B.R.G.M. Expert Geologist, Chief of Mission

I. INTRODUCTION

This report is the progress report of the French Bauxite Mission in Thailand for the period January-March 1962.

In accrodance with the programme contemplated in our preliminary report of 30 December 1961, the first prospection work was carried out in certain zones of the mountain ranges bordering the Khorat plateau to the West, a region immediately adjacent to the Mekong basin proper.

The work of the mission was practically interrupted during the month of February due to an illness incurred on the field and the subsequent stay of the expert in hospital in Bangkok.

I wish to thank the engineers and the personnel of the Department of Mines for the assistance they have given me on several occasions. I am especially indebted to my assistant, junior geologist Mr. Sidhi Suddhibongse, who has constantly accompanied me on the field and who has also facilitated my contacts with the local population, from which the mission recruited several workers needed for reconnaissance work. Mr. S. Suddhibongse has also assisted me in various work in Bangkok.

/ II.

II. MOBILIZATION OF THE MISSION

(1) Equipment

During the month of February, we have taken delivery of the Land-Rover vehicle for which we had placed an order, for the mission, immediately upon our arrival in Bangkok in early December 1961 with the local agent for Land-Rover, Edgar Brother Ltd. For our movements during the month of January, we had at our disposal a Land-Rover of the Department of Mines.

We took delivery in Bangkok of the rest of the exploration and camping equipment, which was sent by sea and air and which had been ordered by the Bureau of Geologic and Mining Research (B.R.G.M.) in Paris.

Hereafter is the list of the main articles of equipment provided to us by B.R.G.M.:

- Land-Rover field vehicle ("pick-up truct 109" type) with winch;
- Wild ST3 theodolite with 3x magnifying equipment;
- Mattey theodolite, 195 and 196 models;
- "Chaix" surveyor's table;
- 2 20m metal surveyor's ribbons "Topochaix";
- "Universelle" type "Chaix" compass;
- 2 "La Broussarde" type "Chaix" compasses;
- Thommens altimeter;
- Various other geologists instruments (Estwing hammer; hand pedometer, magnifying glasses; knapsacks; zinc map tubes; polyethylene, paper and cloth sample bags);
- Kodak Retinette camera;
- 8 x 40 MILLI-BBT-KRAUS field glasses;
- Japy typewriter;
- First aid kit;
- Various technical books;
- Topochaix draftsman table with folding legs;

/ - Miscellaneous

- Miscellaneous drawing equipment (metal set for Wild compass, Kodatrace, tracing paper, etc.);
- Miscellaneous camping equipment (tent, camp bed, folding chairs and tables, Electrolux petrol refrigerator, food containers, pressure lamp (petrol), Lambert water filter, etc.).

(2) Office space

The Department of Mines recently provided us with a new large office. This is a very suitable room, recently constructed and annexed to the petrography laboratory. The furniture which is still lacking (for instance shelves) has been ordered.

III. ACTIVITIES IN BANGKOK

Among the mission's activities in Bangkok, let us mention in particular:

- Our laboratory work directly concerned with bauxite research included stereoscopic examination of aerial photographs covering a large part of these geological areas which appeared to be the most promising from the point of view of possibility of bauxite deposits.

This study enabled us to identify and delineate the zones which appeared to be the most favorable from a geomorphological point of view and, consequently, to undertake direct reconnaissance on the field in those areas.

- During the month of January, I was visited by Mr. J. Lautard, B.R.G.M. Counsellor for Asia and South-East Asia. I discussed with him certain aspects of the mission's programme.

- On 18 January, I attended a meeting presided by Mr. V. Setharut, Director of the Department of Mines. This meeting also included Mr. J. Lautard, and M. Nitipat Jalichandra, Deputy Director of the National Energy Authority, as well as Mr. Saman Buravas, Mr. Pisoot Sudasna, Mr. Jumchet Javanaphet, Mr. Kaset Pitakpraivan and Mr. Sidhi Suddhibongse of the Department of Mines. The object of the meeting was to discuss the details of the Plan of Operation of the bauxite Mission.

/ - At Kasetsart

- At Kasetsart University at Bang Ken, I contacted Mr. F.A. Moormann, FAO soil expert, and Mr. Sarot Montrakun, soil expert of the Rice Department of the Ministry of Agriculture, with whom I had long discussions concerning laterites. Their information added interesting additional data to my knowledge of the laterite formations recorded to-date in the four countries covered by the bauxite mission (see also Bibl. Nos. 2, 8, 9, 10, 11, 12, 13, 14, 15, 16, 18, and 19).

To my knowledge, the existence of bauxite in Thailand is recorded in two documents only, viz.:

(1) The report, drafted in Siamese, by Mr. Samak Buravas, formerly an engineer in the Department of Mines, who thinks he may have found high-content bauxite on a limestone hill, known as Khao Kralok, in the vicinity of Kok Samrong, to the NNE of Lopburi (Bibl. No. 3).

(2) The report by Mr. J.A. Richardson, noting an occurrence of bauxite in the area of Kanchanaburi (Bibl. No. 17; Annex III).

The translation section of the Mekong Committee has just prepared the final French and English translations of Mr. Samak Buravas's report, as well as the report, also drafted in Siamese, by geologists Nitipat Jalichandra and Kaset Pitakpraivan, on their checking in 1948 of the bauxite formation mentioned by Mr. Richardson. For information, the above-mentioned reports are annexed to this quarterly report, respectively in English and French (see annexes II, III, IV).

- Drafting of a paper on the chemical and physical analyses of bauxite (Bibl. No. 5) and of monthly progress reports for Mr. J. Lautard of B.R.G.M. in Paris.

- Selection of about 20 samples from the prospected limestone areas. Those samples are to be analysed in the B.R.G.M. laboratory in Paris and in the chemistry laboratory of the Department of Mines in Bangkok. It would be interesting to identify, in that series of samples, the chemical relations between, on the one hand, the sound permo-carboniferous limestones and, on the

/ other hand,

other hand, the weathered limestones, the recent limestones tuffs, the clays in limestone features and the limestone-clay sediments deposited in alluvial plains. It is possible that some of those deposits were enriched in free alumina during a recent, warm and extremely damp period.

IV. GEOLOGICAL INVESTIGATIONS

Considering that the geological constitution of the Khorat Plateau, which covers the Thai part of the Lower Mekong Basin, did not appear promising to us as regards the formation of bauxite, we decided to concentrate our main investigations in the adjacent region to the West of the Khorat Plateau (see Bibl. No. 4).

In the rugged area, geologically extremely varied, which borders the Khorat Plateau to the West, and is generally oriented North-South, we first selected certain zones of permo-carboniferous limestone formation and of ancient certain eruptive rocks (see also maps I and II).

The following is brief summary of our geological investigations in the prospected areas:

A. Petchabun area

In our prospection programme, reconnaissance work was first carried out in the large plateau located to the West and N-W of Petchabun, a town on the Mae Nam Pa Sak River, about 300 air kilometers to the NNE of Bangkok. This plateau, which according to the 1/250,000 topographic map rises from 500 m to over 1,000 m above the alluvial plain of Mae Nam Yom and Mae Nam Nan Rivers to the West and of Mae Nam Pak Sak river to the East, appeared highly interesting, for the following reasons:

(a) According to the 1/2,500,000 and 1/5,000,000 geological maps (see Bibl. No. 2 and map I) the plateau is composed of two large intrusive and effusive formations, represented by dioritic, andesitic and rhyolitic rocks, which are generally favourable to the formation of bauxite-bearing laterite cortexes.

/ (b)

(b) Preliminary study of the stereoscopic aerial photographs showed that this was a large plateau, in the full sense of the word, and therefore a very favourable morphological formation.

(c) The plateau is covered with vast dense forests, but examination of the aerial photographs revealed the existence, in particular in the middle and on the southern part of the Plateau, of several zones with stunted vegetation and very light forest. A priori, this special type of vegetation, covering areas of one or two, or several square kilometers, might point to the existence of large lateritic cortexes.

The plateau was reconnoitred in its southern part, to the NE of the large village of Ban Wang Pong, in the vicinity of the hamlet of Ban Khlong Nam Keng (see Annex I, photos No. 1 and 5). Its southern rim forms a very rugged relief over practically all of its length, i.e. about 25 km. This remarquable relief, towering from 600 to 700 m above the plain is partly occupied by impressive rocky cliffs of difficult access.

Geological reconnaissance showed that a sub-horizontal sandstone formation, presenting at many places a criss-cross stratification and certainly related to the Khorat series, overlies an accumulation of various volcanic rocks (among which we have identified volcanic breccia flows) of a depth of 4 to 500 m or even more.

Those two formations can be distinctly observed on the high denuded cliffs, which are visible from a long distance, on the southern edge of the plateau; the contact is very clear between the sandstone strata of the Khorat series on the upper part and the non-banded rocks of the volcanic series lower down (see annex I, photographs Nos. 5, 6, 8 and 9).

During the reconnaissance of the southern part of the plateau proper - a section which rises toward the North and North-East progressively up to a height of about 900 m or more - we have found no trace of laterization, which is not surprising considering that the plateau proper is composed only of a succession

/ of quartzy

of quartzy sandstone layers (see also annex I, photograph No. 3). The surface weathered layer is represented by clayey sandy soils, grey or brownish in colour, which are never ferritic. Furthermore, we found that the zones with stunted and light forests are peculiar vegetations related both to altitude and to the presence of a number of large blocks and sub-horizontal outcrops of the Khorat sandstones. There is no laterite cortex.

After checking the geology of the southern part of the plateau, the sandstone formation of Khorat, which is everywhere sub-horizontal and well stratified, can easily be followed toward to the North and North-West on the pairs of stereoscopic aerial photographs. Its depth probably reaches several hundred metres. It appears to occupy the entire plateau, except (a) the ruggod eastern zone which is composed of other formations (metamorphic and volcanic) concerning which we do not have any more detailed information, and (b) a somewhat lower part of the N-W section of the plateau, to the East of the village of Ban Mung, where the volcanic series, much furrowed by erosion, appears over a certain area; this outcrop is due to the destruction of the Khorat sandstone cover by recent erosion.

According to the geologists of the Department of Mines, the sandy, sub-horizontal and well stratified formation of the Khorat series is clearly apparent, in the shape of large, high rocks, all along the western side of the Friendship Highway linking the towns of Pitsanuloke and Lom Sak.

Conclusions

(a) It would appear that bauxite-bearing laterite cortexes are not to be expected on the vast plateau described above.

(b) Contrary to what is indicated on the geological maps, we may now say that the plateau proper is mainly constituted of sandstone of the Khorat series, overlying a large formation of volcanic rocks.

Two explanations are possible:

- The volcanic

- The volcanic series may represent a sill interpolated in the Khorat series. In that case, the volcanic rocks might be of the tertiary era, which is the new held by the Thai geologists. However, considering the great depth of that formation and the presence of volcanic breccias, we feel that the formation is unlikely to be a real sill.

- The sandstone series of Khorat deposited on a previous volcanic series, which would then be earlier than the triasic period.

Only a detailed examination of the contact between the volcanic series and the sandstone series as exposed on the high cliffs, together with the petrographic analysis of the volcanic rocks and the interstratified polymikt conglomerates in the sandstone, could provide a final solution to this interesting geological problem.

Documents

- Topographic map at 1/250,000 Muang Petchabun sheet, NE 47-16, series L-509.

- Aerial photographs (approximate scale 1/40,000) Nos. 5962-5968, 6578-6584, 6655-6662, 6680-6687, 6760-6769, 6788-6798, 6851-6865, 6939-6960 et 6979-6989.

B. Limestone areas

Prospection work was also carried out in some zones of limestone rocks in the Ratburi permo-carboniferous formation, with a view to studying the possibilities of bauxite in karstic terrains.

(1) Kok Samrong area

A preliminary reconnaissance was conducted in the area of Kok Samrong to check the bauxite occurrence recorded at Khao Kralok by Mr. Samak Buravas (Bibl. No. 3; Annex II).

/ Khao Kralok

Khao Kralok is located some 30 km NNE of Lopburi, about 3 km South of Kok Samrong. This is an isolated limestone knoll - probably a residual erosion knoll - located in a vast alluvial rice plain. Khao Kralok is a disused quarry of road-building materials; it is linked to the Lopburi-Petchabun road by a motor track, of a length of a few hundred metres.

The knoll is 10 to 20 m high. It is formed of massive grey subreef limestone, belonging to the Ratburi permo-carboniferous formation, with some relatively unimportant intercalations of highly weathered limy argillites. The limestone is crystalline ("spathic") and organogenic. They contain abundant debris of encrine stems and also polyps.

At the foot of the West slope of the knoll the limestone masses are interlarded by a, probably sub-vertical, seam from 10 to 60 cm wide and oriented NW-SE. This seam outcrops over a distance of several dozen metres. Its northern part is composed of a very roughly crystallized calcite; the seam then turns suddenly into a roughly brecciated vein, including heterogenous elements, represented mainly by angular debris (of varying dimensions) of the following rocks: Ratburi grey fossil-bearing limestone, black clayey shist (from the Kanchanaburi Series?) and white seam quartz. This breccia also contains malachyte flies, and, very frequently, pyrite (and also chalcopyrite?).

We have not observed any bauxite at Khao Kralok. It is possible that the "white pisolithic bauxite" mentioned by Mr. Samak Buravas was confused with the "travertine" (or"limy tuff") type deposit which is found in several spots. It appears to us that this deposit was formed in superficial limy waters, probably during a recent warm period. It consists in a limy substance, frequently hard with a dense or finely banded texture, of whitish, yellowish, pinkish, beige and grey colours. This substance, which is also probably kaolinized in part, forms shallow local crusts over the "Ratburi" limestone masses (see annex I, photograph No. 13) and some narrow "strips" on the banks, which in some places reach the foot of the knoll. It also fills certain local shallow dissolution cracks in the "Ratburi" limestones. (see annex I, photograph No. 14). This substance often contains sound or wheathered angular fractions of

/ fossil-bearing

fossil-bearing permo-carboniferous limestone, which have the aspect of a breccia.

We have sampled the various formations. Some samples will be analyzed to determine the content of compound alumina (kaolinite) and also to check on the possible presence of free alumina.

About ten kilometres South-East of Kok Samrong, South of Ban Phaniat village, which is located on the Lopburi-Petchabun road, there is a large monoclinal structure (dipping eastwards) constituted by hard well banded sandstones belonging to the Khorat series. This sandstone mass has a length of over 10 km and is oriented NNW-SSE to NW-SE. There are no traces of laterite.

Documents:

- Topograhic map at 1/250,000, Ban Mi sheet, ND 47-4, series L. 509
- " " " , Ayuthya sheet, ND 47-8, series L-509
- Aerial photographs (approximate scale 1/40,000) Nos. 21536-21542 and 4237-4243.

(2) Sai Chanuan Area

To the North of the Frientship Highway from Saraburi to Nakhon Ratchasima (Khorat) lies a large limestone area, separated from the Western rim of the Khorat plateau by the relatively narrow valley of the Lam Phraya Klang.

In this region, principally covered by the Ratburi permo-carboniferous formation, we have explored a hilly zone near Sai Chanuan village, which is located about 18 km to the North of Pak Chong (Pak Chong is a small town on the Friendship Highway, about 70 km from Saraburi).

Sai Chanuan is located at the eastern foot of the eastern range of the limestone area, on the western edge of the alluvial plain of Lam Phraya Klang river, which flows northeward at the foot of the high western rim of Khorat plateau (see also Annex I, photo No. 16). This Sai Chanuan area was selected for field investigations after previous examination of the aerial photographs.

/ From a

From a geomorphologic point of view, it is characterized by the following features:

(a) The existence of a large "low plateau", oriented NNE-SSW, about 10 km long, 2 to 4 km wide, and at a level 100 to 150 m above the elevation of Sai Chanuan village (see also annex I, Photographs Nos. 15, 17, and 18). This low plateau has a slightly rolling terrain; it is cut by several talwegs, which are generally shallow. For several crops the forest cover of the plateau has recently been burnt and cleared over large areas (see annex I, Photographs No. 15, 17, 18, 19 and 20). The floor presents several knolls of well banded limestone rock, oriented NNE-SSW (see also annex I, Photograph No. 15).

The low plateau proper is covered with clayey soils, brownish or greyish in colour ("rendzina" type soils or "carbonated hunic soils?").

At several places - in particular in the talwegs, on the (motor) track which crosses the "low plateau" up to its N rim, and on the slopes corresponding to slight changes in the relief - we observed outcrops composed mainly of grey or dark grey limestone of a crystalline and organogenic type (in particular, with encrine stems debris), of more or less sandy or even, in places, strongly silicified, grey limestone, and hard, siliceous and limy dark-grey to black-grey argillites. All these rocks are well banded and apparently alternate within a single sedimentary series. From East to West, their direction varies from N10° - 30°E to N40° - 60°E. The layers are subvertical and mostly show a very marked dip (60° - 80°) towards the East or South-East.

At one location, in a talweg several meters deep, in the Northern part of the low plateau, we found a large outcrop of grey shale with limy shards. They may belong to the Kanchanaburi series.

(b) To the East, the "low plateau" of Sai Chanuan area is rimmed by a practically straight range of hills of a height of 80 to about 200 m above Sai Chanuan village. This range, which is oriented NNE-SSW, is composed of

/ the same

the same geological series as that observed on the "low plateau"; a well banded alternation of grey or dark grey fossil-bearing limestone (including encrine debris) siliceous limestones (highly silicified locally) and hard argillites, both siliceous and limy. The direction is N10° to 20°. Dip is subvertical or 60° to 80°E.

(c) To the North and West, the "low plateau" is rimmed by limestone ranges which dominate it by 100 or 200 m approximately (see also annex I, photographs Nos. 18, 19, 20 and 21). These reliefs are composed of massive organogenic, sub-reef limestone, grey to dark grey in colour, with a dense texture, or, in many cases, crystalline ("spathic") with abundant encrine debris. In some places we have also observed polyps. These limestones are very typical of the Ratburi permo-carboniferous formation. This high massive limestine range is characterized by the presence of deep steeply banked depressions, of a diameter of a few hundred meters up to 1 km approximately. These are karstic forms of the "doline" type.

Our explorations for bauxite were specially concentrated on the two most remarkable geomorphologic units, namely, the "low plateau" and the "doline" type depressions in the high limestone areas. But we found bauxite-bearing occurrences there, nor on the terraces abuting the peaks of the limestone range.

The "low plateau" does not have any specially characteristic topography; it does not constitute a real "polje" or karstic plain.

There is no deep karst in the limestone masses which were explored. We found there only superficial karst: in the abovementioned dolines, in numerous dissolution fissures and cavities, and in the frequent lapiaz incisions on the face of the massive limestone (see annex I, photographs No. 22 and 23).

Concerning the soil forms, we have observed the "soil chain" (or "catena") which is characteristic of limy terrains and contains the following succession of soils as a function of the relief:

/ (a) Red or

(a) Red or brownish red (iron-bearing soils) decalcification clays known as "terra rossa", on the summit terrace and on the low slopes. The bottom of the deep depressions (dolines) are also carpeted with "terra rossa", but we are under the impression that this clayey cover is never very thick, because in the depressions observed we often noted small outcrops or rocky humps of sound substratum limestone (see also annex I, photographs Nos. 24 et 25).

(b) Black and grey-black or brownish clays on the external slopes of the ranges and on the walls of the deep dolines. These soils, which are generally related to the large limestone outcrops, may be assimilated to the "rendzina" type.

We have taken samples of all the above clay soils.

In view of the negative results as regards bauxite, we felt it would not be useful to continue the prospection work in the limestone area on the Northern side of the Friendship Highway, considering that, on the basis of the stereoscopic aerial photographs, that area presents in its other parts the same geologic and morphologic aspects as the Sai Chanuan zone which was explored.

Documents:

- topographic map at 1/250,000, Ayuthya sheet, ND 47-8, series L-509
- " " " , Ban Mi sheet, ND 47-4, series L-509
- aerial photographs (approximate scale 1/40,000) Nos. 3714-3720, 5058-5065, 3947-3953, 4192-4198, 18333-18336 et 4368-4374.

(3) Saraburi-Lopburi Area - Limestone area to the South of the Friendship Highway, Thap Kwang-Pak Chong zone

The high limestone terrain, belonging to the Ratburi permo-carboniferous formation, which rises half-way between Saraburi and Lopburi and in the Thap Kwang-Pak Chong area to the South of the Friendship Highway, presents very similar geomorphologic aspects. There are hills, more or less separated from each other by karstic river erosion, dominating the low plains by several

/ hundred

hundred metres. In the intermediate relief zones there are numerous knolls and high residual hills, with steep slopes, resulting from an advanced phase of karstic river erosion (see also annex I, photograph No. 28).

The hills, which are mainly formed of hard masses of grey limestone, extremely organogenic (including encrines and polyps), also have a very sharp relief with irregular crests and peaks and a large number of more or less closed depressions. Let us also note their abrupt slopes, the upper part of which consists of large rocky cliffs or even vertical faces (see also annex I, photographs Nos. 29 and 30).

The topographic depressions, which are generally very deep, isolate the crests and peaks. Their diameter varies from a few hundred meters to about 1 km. These depressions, which may be assimilated to the "doline" karstic type, were specially studied during the reconnaissance work. They are clearly perceptible on the couples of stereoscopic aerial photographs. The elevation of the botton of the depressions inspected is 100 to 150 m above the surrounding low plains.

The two regions we are concerned with here, form a "peak landscape", a geomorphologic aspect which appears to be typical of tropical karsts.

As in the limestone area to the North of the Friendship Highway, we have not found any bauxite occurrences in the limestone masses which were investigated in the areas of Saraburi-Lopburi and of Thap Kwang-Pak Chong.

Superficial karsts are very frequent, in the form of dolines, lapiaz, and dissolution fissures and cavities. On the other hand, typical deep karst is probably rare and of limited amplitude. We found only one stalagtite grotto, at high level and with a depth of only a few metres. This grotto is located beneath a vertical limestone cliff, at the foot of the large northern face of the range, 6 to 8 km to the East of Thap Kwang.

Here again, the soil types are "Terra rossa" and rendzina" clays. "Terra rossa" fills the bottom of the dolines in the high limestone masses and covers large areas of the low plains traversed by the Saraburi-Lopburi road, the

/ Friendship

Friendship Highway and the new road southwards from Pak Chong to Khao Yai National Parc. These red and brownish red clayey soils often contain inumerable shards of wheathered limestone, as well as small ferruginous concretions.

In some cases, we also observed in the limestone masses long fissures or large cavities(due to dissolution), which have been filled with hard clays, red or grey in colour, containing much jagged debris of heavily weathered limestone.

We have taken samples of all the above clay formations, and some of the samples will be analysed.

To the SSW and SW of Pak Chong, in the plains, we observed deposits of roughly banded limestones, in many cases pitted with cavities and yellowish, grey or beige in colour, as well as limy clays or clayey limestone (marly sediments) white or grey-white in colour, containing numerous light-coloured hard limy concretions, which are probably recent river or lake deposits. The limestone-clay sediments are perhaps partly kaolinitic and it is even possible that they may have been enriched in free alumina during a warm and very humid epoch.

Documents:

- Topographic map at 1/250,000, Ayuthya sheet, ND 47-8, series L-509
- Aerial photographs (approximative scale 1/40,000) Nos. 2865-2872, 2710-2717, 5120-5130 et 2636-2644.

Additional geologic data

(1) As we were following the new road from Pak Chong to Khao Yai National Parc, we noted that the limestone area to the South of the Friendship Highway was delineated southwards by a large crystalline range, with numerous gulleys, and that further South, there is a reappearance, at high altitude, of the Khorat series sandstone formation, i.e. in the hills of Khao Khieo and Khai Rom Noi.

/ This new

This new road, which is still under construction, is already over 40 km long. Its culminating point (at Heo Thap Kabung) is about 500 m above the level of Pak Chong. After crossing the limestone area - i.e. approximately after the entrance to the National Parc - the road rapidly rises up the narrow and steep valley of the Lam Huai Takhrong into the range of crystalline rocks (porphyries and metamorphic volcanic rocks). The soils on the terraces and slopes of this range include red ferritic clays. However, we have not observed any lateritic cortexes.

(2) During a rapid reconnaissance in the hill zone about 8-15 km to the North-East of Lopburi, we noted that the volcanic formation (andesites, basalts, etc.) which constitute most of the higher reliefs is covered over a part of its southern rim by limestone of the Ratburi permo-carboniferous formation. This limestone forms cliffs which may be observed from the North and which crown the summit of some of the high reliefs. This limestone series appears to have a strong dip toward the West or SW (see also aerial photographs No. 3773-3776 and 7041-7044). But we have not had enough time to study this question in full detail. Only detailed geological surveys would make it possible to determine the geologic structure of the zone and, in particular, show whether the volcanic rocks constitute an enormous sill or whether the "Ratburi" sedimentary limestone has deposited over a previous volcanic formation.

(3) We also visited the area of Khorat (Nakhon Ratchasima) to verify the presence of the lateritic cover said to exist in the vicinity of Khorat, a few kilometres to the South of the Friendship Highway. However, this is not a lateritic formation but a vast river terrace forming a gentle relief, observable also along the Friendship Highway (13 km from Khorat) as well as more to the North. This terrace is composed of layers of heterogeneous pebble gravel mixed with red clay. The profiles of these layers are clearly exposed in the large quarries from which the local population extract gravel. This river deposit contains numerous, and in some cases quite large, fragments of silicified wood.

/ We made

We made use of this opportunity to make observations along the Friendship Highway on the SW part of the Khorat Plateau, which offers a perfect tabular landscape. Red ferruginous soils are frequent, but there is no cortex, nor any ferritic soils, even on those areas that are presumably be covered by layers of decomposed argillites.

This brief additional reconnaissance also revealed that despite its very favourable gemorphologic conditions, the geological constitution of the Khorat Plateau is not conducive to the formation of bauxite-bearing laterites.

V. CONCLUSIONS

- The results of our first prospection work in Thailand are nagative from the point of view of bauxite.

- The lateritic covers investigated so far in Thailand by geologists and soil experts, are all extremely ferruginous (see Bibl. No. 2, 8, 10, 11, 12, 13, 14, 15, 16, 18 and 19).

According to the descriptions and analyses given in our documentation, it seems to us that, with a few exceptions, these localized ferruginous covers represent the pedological results of an absolute accumulation of iron oxides by oblique washing and lateral inflow (see also Bibl. No. 6). This process, which is related to the action of the water tables, influences inter alia : (a) the lower slopes of the hills; (b) the changes in slope corresponding to the zones of natural drainage (e.g. along the banks and at the level of springs); and, (c) the river terraces or other flat zones overlying impervious clay substrata.

In brief, the laterites observed so far in Thailand do not generally constitute true cortexes - either "recent" or "fossils" - of the residual type, formed in situ by a relative accumulation of iron and aluminum sesquioxides in a soil profile of residual clays originating from underlying alumino-silicated rock, such a ferritic medium being the only one to admit a sufficient (relative) accumulation of alumina to form bauxite-bearing cortexes.

/ - The bauxites

- The bauxites mentioned by Mr. J. A. Richardson (Bibl. No. 1, p. 155; Bibl. No. 17; Annex III) and by Mr. Samak Buravas (Bibl. No. 3; Annex II) were verified by Mr. Nitipat Jalichandra and Mr. Kaset Pitakpraivan (Bibl. No. 7; Annex IV) and also by myself.

It would appear that in fact they are limestone deposits of recent epoch.

- Certain areas of Thailand have not yet been subjected to a detailed soil survey. In particular, such areas ubclude the upper terrains, of difficult access, of ancient limestone formations.

In consequence, it would appear reasonable to continue investigations in the limestone areas to check the possibility of bauxite in karstic terrains.

VI. SCHEDULE OF WORK

During the months of April, May and June, we shall continue bauxite investigations in Thailand. We have scheduled in particular a reconnaissance in the area of Kanchanaburi, where important karstic occurrences have already been noted in the paleozoic limestone formations.

In agreement with Mr. J. Lautard, we shall take home leave in Europe at the beginning of next July. We shall be on for a period of three months.

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VII. BIBLIOGRAPHY

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(19) Société grenobloise d'études et d'applications hydrauliques (SOGREAH) : "Etude agro-pédologique du bassin supérieur de la Nam Chee" (Thailand) (September-October 1959)

- Map I - Approximative geological map of Thailand, scale 1/5,000,000
- Map II - Zones surveyed by the French bauxite mission

- Annex I - Explanation of photographs Nos. 1 - 30
- Annex II - Report by Mr. S. Buravas (Bibl. No. 3)
- Annex III - Paper by Mr. J.A. Richardson (Bibl. No. 17)
- Annex IV - Report by Mr. Nitipat Jalichandra and Kaset Pitakpraivan (Bibl. No. 7)

ANNEX I

Petchabun area

Photograph 1 : Hamlet of Ban Khlong Nam Keng, our first camp, at the southern tip of the plateau, West of Petchabun.

Photograph 2 : Mobile jungle camp on the southern slope of the plateau (altitude: approximately 400 m above the alluvial plain).

Photograph 3 : Large outcrops of well banded subhorizontal Khorat sandstone in the bed of a stream in the southern part of the plateau (altitude: about 750 m).

Photograph 4 : View of the southern slope of the plateau, facing southwards. In the background: the mountain range at the southern edge of which lies the Petchabun-Chondaen road.

Photograph 5 : View of the southern rim of the plateau above Ban Khlong Nam Keng hamlet. This view shows the contact between the subhorizontal banded sandstone Khorat series in the top part, and the non-banded formation of volcanic rocks in the lower part.

Photograph 6 : Detail of the preceding. Telephotograph giving a clearer view of the very sharp contact between the Khorat sandstone formation and the non banded volcanic series.

Photographs 7, 8 & 9 : Other views of the high southern rim of the plateau, to the NW and NNW of Ban Khlong Nam Keng. They also show the contact between the upper banded sandstone and the lower volcanic series.

Photograph 10 : Another view of the southern rim of the plateau. This shot was taken from the alluvial ricefield plain, about 6 km to the West of Ban Khlong Nam Keng.

/ Photograph 11:

Photograph 11 : View of the western rim of the plateau. This shot was taken from the alluvial ricefield plain near the large village of Ban Wang Pong, on the River Khlong Dong Takhop, whose right-bank upper-reach tributaries drain the southern slop of the plateau.

Photograph 12 : Trouble on the track from Ban Wang Pong to Chondaen. An unforeseen obstacle which caused much delay: namely, a large wood transporting truck with a flat, which for lack of a spare wheel had to be repaired and inflated on the spot.

Koke Samrong Area

Photograph 13 : Khao Kralok, "Ratburi" limestone knolls, near Koke Samrong. A recent superficial deposit of "limestone tuff", forming a whitish crust overlying the permo-carboniferous limestone.

Photograph 14 : Khao Kralok. Dissolution fissure in the "Ratburi" limestone, filled with whitish "limestone tuff".

Chai Chanuan Area

Photograph 15 : This view was taken from the limestone knoll above the village of Sai Chanuan to the West. It shows the "low plateau" (la gely burnt and cleared) the floor of which presents several limestone knolls. In the background: part of the range of high massive limestone hills bordering the "low plateau" to the West.

Photograph 16 : A view taken from the limestone knoll above Sai Chanuan facing eastwards. This photograph shows the alluvial plain of the Lam Phraya Klang and, in the background, the western rim of the Khorat plateau.

/ Photograph 17

Photograph 17 : Late (dry season) brush fire on the "low plateau" in Sai Chanuan area. Destruction of forest cover by man for agricultural purposes. The Fire has a relatively deep action on the soil.

Photograph 18 : Large clearing work in the middle of the "low plateau" to the west of Sai Chanuan.

Photographs 19, 20 : Important clearing work in the NW zone of the "low Plateau", bordered to the West by high massive limestone hills with rocky cliffs. The little white spots at the foot of the range on photograph 19 are blocs of limestone debris.

Photograph 21 : Northern rim of the "low plateau". It is enclosed by a high range of massive limestone.

Photographs 22, 23 : Massive lapiaz limestone blocs.

Photographs 24, 25 : Large outcrop of sound massive limestone at the foot of the rocky knoll at the bottom of a large topographic depression ("doline" karstic type) in the high range shown on photograph No. 21.

Thap Kwang - Pak Chong Area

Photographs 26, 27 : Disused quarry of revetment material off the Friendship Highway, in the low plain, about 15 km from Pak Chong. The photograph shows the red clayey soil (with small ferruginous concretions) of the "terra rossa" type, which covers the massive karstified limestone of the Ratburi permo-carboniferous formation.

Photograph 28 : Limestone area to the SW of Pak Chong.
This shot was taken facing eastward from a dam constructed in a NS direction between two massive limestone ranges.
Fore and middle ground: a large pond (almost dry in the

/ middle

middle of the dry season) dug in the low plain for irrigation of the large cultivated areas (mainly covered with "terra rossa") in the low plain extending westwards from the dam. The floor of this basin consists of grey, compact sedimentary clays, with reddish ferruginous spots. In the background: a series of residual limestone hills produced by an advanced phase of karstic river erosion.

Photographs 29, 30 : Massive limestone ranges, in the vicinity of the new Pak Chong - Khao Yai National Parc highway, showing some of the characteristic morphologic aspects of the massive limestone formations: high rocky cliffs and vertical faces. The plain is covered with red clayey soils, which are "terra rossa" type ferruginous soils.

Annex II

Report on geological investigation of aluminium ore at Khao Kralok, Amphur Koke Samrong, Lopburi
(10 February 1945)

Samak Buravas

Type of ore

The ore is hydrated aluminium oxide in composition, containing a little calcium carbonate and psilomelane.

Analysis of clean samples: Al_2O_3 - 85%, SiO_2 - 2%, CaO - 2%, Ignition loss - 8%, Mn and Fe - traces.

Analysis of ore samples: $Al_2O_3 + Fe_2O_3$ - 74,76%, SiO_2 - 4,36%, CaO - 15,6%, Ignition loss 5,4%.

So the formula after computation is $2Al_2O_3.H_2O$.

This ore dissolves in diluted HCl and H_2SO_4 and produces gas from $CaCO_3$. After heating, the samples are insoluble in acids.

Hardness 3,5; pisolite from $\frac{1}{2}$ to 1 cm in size, white, mostly massive, with a banded appearance.

History

While investigating iron ore for the Thai Cement Company Ltd, April 20, 1941, the author and Mr. K.A.H. Buss, an iron ore expert from Sweden, and Mr. Sae, found bauxite at Khao Kralok for the first time, in a road construction quarry. The expert and the author thought that it was a kind of opal ($SiO_2.nH_2O$), no one paid any attention to it, and the samples were left for years.

Later, in July 1944, the author noted that it appeared to be a zinc silicate. Analysis was then effected. The author learned from Mr. Samrerng, Head of the Chemical Division, that it was not zinc ore but aluminium ore. And he found other occurrences of this type of ore at Khao Poon near Krabinburi railway station.

/ In September

In September 1944, the writer had the opportunity to go to Khao Poon. He found that the ore occurred in pockets of grey crinoidal limestone. It looks similar to that at Khao Kralok, but here the limestone was intruded by quartz monzonite porphyry.

In view of the relation between crinoidal limestone and aluminum ore, the writer has an idea that the ore should occur along the escarpment of the Korat Plateau. Such high content ore can be smalted for aluminium or asbestos production. That is why the Technical Division of the Mining Department decided to investigate the aluminium ore at Khao Kralok.

Situation

The ore occurrence is located at Khao Kralok, Amphur Kobe Samrong, Lopburi, at km 180 along the Lopburi - Chaibadan road.

Communications

There is a road from Lopburi to Chaibadan. The ore deposit is 1 km east from km 180 on this road. There is a bad road to Khao Kralok. In the rainy season it cannot be used by car. Beside this there is a cart track passing at the foot of the hill to the railway station.

Geography

The area is the slope of the mountains, dipping to the river to the north. To the south there is a range of mountains known as Khao Nang Phra Chan which is about 600 meters high. There are some hills in this area such as Khao Tab Kwai, Khao Sapan Nak and Khao Kralok itself which is 20 m high. The surrounding land is paddy fields and forest. There are 2 or 4 creeks, but the whole area lacks water; even the biggest stream, the Huai Pong, which flows at a distance of 5 km from Khao Kralok is dry in summer.

Geology

The lowest formation is calcareous shale and sandstone found under limestone layers at Khao Sam Yod. The limestone itself is black in colour and contains fossils of the Lower Carboniferous era. The strike is NW-SE dipping to the West.

/ The fold

The fold axis lies westwards behind Khao Sam Yod, curving in a NW-SE direction, although the geological structure is not entirely clear, as shown by the presence of shale, also behind Khao Sam Yod.

The correlation of the crinoidal limestone and massive limestone is not quite clear, however, the fossils indicate a younger age for the crinoidal limestone.

At Koke Hin Lai red limestone conglomerate overlies the limestone which is intruded by quartz monzonite porphyry. This rock is mostly altered and is found in the area of Khao Nang Phra Chan, Khao Rae and Khao Cha Khaon. At Khao Ta Paw, at km 196, the rocks are quartzite and pebbly quartzite: strike is N-S, dip 15° E.

Olivine basalt is found at Khao Jora Kae and from this mountain to Chaibadan it is entirely volcanic rock.

There are boss outcrops of quartz diorite in the western part of Khao Nang Phra Chan, in contact with porphyry. They show very strong compression, for the crystals are parallel and have the same aspect as gneiss. To the north this type of rock is in contact with the limestone of Khao Tab Kwai, which is the origin of the contact metamorphic iron deposits there. To the west it also intruded the limestone of Khao Kok Katium. High temperature quartz veins are associated, thus producing large metamorphic contact zones.

Stratigraphy, from old to young

Calcareous shale, quartzite	- Pre-Carboniferous
Black limestone	- Lower Carboniferous
Grey crinoidal limestone	- Permo-Carboniferous
Red limestone conglomerate	- Permian?
Altered quartz monzonite porphyry	- Permo-Triassic
Quartzite and pebbly sandstone	- Post-Triassic
Basalts, trachytes, etc.	- Triassic?
Quartz diorite	- Cretaceous?

/ Local

Local geology

Precipitated lime was found near the road at km 180. It looks similar to the shale at Khao Sam Yod.

At Khao Kralok the coarse grained limestone contains a great deal of Crinoids so that it might be termed crinoidal limestone. On altered surfaces the fossils are clearly seen. At this hill there is a band of breccia composed of slate, sandstone, limestone and quartz in the calcareous matrix. It lies in a NW-SE direction and is parallel to the strike of the limestone. It is not quite clear whether this is a fault breccia.

This limestone and also the fossils are very similar in appearance to the limestone at Khao Poon near Prachinburi.

The orientation of the hill is N-S. There is no indication of intrusion in the radius of 1 km, but recrystallization shows that the limestone was metamorphosed.

Soil

The soil in this area shows that it was formed in arid climate. The weathered basalt is covered by chocolate-coloured soil. At Khao Ta Paw the soil is sandy by weathering of sandstone.

The laterite found at Hin Som originated from weathering of porphyry. At Khao Ta Kwai and Khao Kok Katium, which are metamorphic areas, the soil is red.

Mineral deposit

The mineral deposit is composed of aluminium ore and breccia of flint and chert. The two ore-bodies show, on both sides, sharp contact surfaces with limestone. Both ore-bodies are about 1-2 m wide. They are wider at the western end and dip to the foot of the hill. They are narrower to the north. Their direction is N 70° E.

/ On account

On account of uncomplete analysis of the limestone, we surmise that this crinoidal limestone contains some residual aluminium from the weathering process. The ore-bodies are located in a faulted zone in the limestone which also contains flint and chert. In the breccia limestone was dissolved by water leaving aluminium ore with breccias of flint and chert. The porphyric rock is not related to the origin of this. The limestone near the ore-bodies contains a little zincblende which might belong to the original composition of the rock.

Conclusion

The two ore-bodies are 2 m wide, 20 m long and reach an apparent depth of 2 m. So the total amount should be at least 320 metric tons.

After analysis of the ore it appears that there is another kind of ore mixed with the aluminium ore, which is: calcium zeolites. Alumina might originate from the weathering of this ore, CaO and SiO_2 being washed away by water, leaving Al_2O_3. This ore is still under analysis.

Annex III

Bauxite formed in situ in alluvium, and laterization of alluvium and limestone in the Mae Khluang and Khwae Noi valleys, Siam

by J.A. Richardson

(Typed copy from the files of Geology Section, Dept. of Mines, Bangkok)

An unusual deposit of bauxite occurs some 5 - 6 miles down river from Kanburi. It lies some 40-50 ft below the top of the flood plane alluvium, through which the river cut a broad gorge. The bauxite occurs in pale grey or greyish white silty clay and is mottled yellowish, buff, and brownish by iron-staining. The deposit is at least 6 ft thick; some 3 ft of it was exposed above river level in February and March 1945. The clay bed is crowded with raggy and irregularly shaped nodular concretions of pale grey and dirty-white bauxite. They are extremely rough and hackly, hard, resistant, pitted and porous; their edges are sharp and cutting. The total thickness of bauxite deposit and the extent of the area covered by it are unknown, but as similar material occurs at Tha Muang about 6 miles farther down stream it might be worth investigating.

There is no doubt that the bauxite has developed in situ from the clay and silty alluvium in which it lies. The hard nodules of bauxite are not sedimentary detritus laid down in a clay bed, but have the cellular structure typical of secondary nodular and concretionary material grown in situ, reminiscent of that of hardened, dried out laterite from Malacca, Straits Settlements. Presumably desilication of aluminium silicate clay-minerals has occurred during comparatively recent times and has produced bauxite as an end product.

It is thought probable that much of the flood-plain alluvium in the river valleys of Siam and Malaya - for exemple, the Sungei Kinta - was deposited in flooded estuaries under marine or brackish-water conditions. If this were so, the bauxite might well have been formed during a more than usually prolonged period when the alluvium, having become elevated above sea-level, was subjected to tropical weathering under monsoonal conditions.

/ Thin seams

Thin seams of pale grey, hard, rough material, apparently crystalline, were formerly exposed at various depths in excavations made in heavy clay alluvium in the officers' Camp at Kanburi. The deepest observed in the camp moat was 12 ft below the surface; it is probably bauxite.

The bauxite of Ponggorang, south-east Johore, Malaya, prospected during 1940 and 1941 by Mr. Hose of Aluminium Laboratories, Ltd., Montreal, occur at relatively shallow depths in swampy and low lying country. Here, the parental cocks are shales, phyllites, volcanic ashes and tuffs, which were bauxitized, so it is believed, under tropical swampy conditions, perhaps a few tens of thousands of years ago. Localized and differential movement leading to recent changes in the relative levels of land and sea have certainly occurred in Johore, for a raised beach, some 15 ft above present sea-level, has been discovered cut in bauxite and capped by a coral reef.

Outline of the Geology of the Area

The hilly country along the Mae Klong and Khwae Noi Valleys as far east as the two small hill ranges immediately south and east of Kanburi is composed almost entirely of crystalline limestone. Farther east shales and phyllites form undulating land north of the river. The extensive flood-plain of this river system is floored probably by argillaceous rocks around Tha Muang and almost certainly by limestone above Kanburi; limestone is visible in the left bank of the river, between Chungkai and the railway cutting nearby.

The depth of the alluvium of which the food-plain has been built by aggradation is variable. Wells sunk in alluvium around Chung Kai are about 30-35 ft deep. At least 25-30 ft of stratified alluvium mostly sandy silt and clay, is visible in the river banks between Kanburi, Chung Kai and Wan Ran. Wells in the officers' POW Camp at Kanburi, sunk into heavy silty clay, grey black and excessively sticky when wet, dusty pale blue-grey and almost rock-hard when dry, were about 50 ft deep. At least 50-60 ft of alluvium is exposed in the dissected flood-plain 5 miles downstream from Kanburi.

/ Laterite

Laterite

Certain thin seams of silty clay in the alluvium of the Khwae Noi in the Group II P.O.W. camp, Chuangkai, have been partly lateritized. They consist of laterite, partly transformed into hard pellets and raggy fragments of limonite, together with blackish brown soft material, probably a mixture of iron hydroxide and manganese dioxide; no definite bauxite deposits were found there. The alluvium at Chungkai is a micaceous silty very-fine sand and mud which drains well and rapidly. It appears to contain notable amounts of colloidal Fe_2O_3, and possibly of colloidal Al_2O_3 in addition, for surfaces of sandy silt exposed to rain beat, wash and general weathering soften while wet and then, hardening as they dry, develop a thin red-brown limonitic cortex.

Lateritization has occurred in limestone and alluvium in many parts of the Khwae Noi Valley. At Wan Ran, five miles above Chung Kai, a cutting was made through a small knoll of limestone. The layer of clay and silty soil resting upon the limestone contained ragged "Kumkar like secondary limestone towards its base, similar to that developed in the desert margin-lands west of Whyalla, South Australia. The upper layers of the original limestone, and the clay and silt in contact with it, had been partly lateritized and stained bright red-brown.

Lateritized alluvium occurs on a river terrace of a tributary of the Khwae Noi, 1 $\frac{1}{2}$ mile above Ban Kao. A flat-topped hill is capped by a bed of pebbly gravel some 10 ft thick. The component pebbles are largely of quartz, chert and quartzite, set in a sandy silt and clay base. The matrix has been strongly lateritized and the iron hydroxide thus formed has set so hard that it was found extremely difficult to break the alluvium, even with picks and crowbars. The section showed:

Terrace Alluvium	(Pebble bed, lateritized ...	approx. 10 ft
	(Clay, silt and sand bed ...	..... 10 ft
Bedrock:	Limestone, massive and crystalline	

The writer has observed somewhat similar lateritic pebble and sand beds in the Sungei Terisi and other streams in north-west Pahang (F.M.S. Topo sheet 2 N/8).

Annex IV

Report on investigation of bauxite deposits in Kanchanaburi (May 1948)

by Mr. Nitipat Jalichandra and
Mr. Kaset Pitakpraivan

Introduction

Considering that Mr. J.A. Richardson, geologist of Malaya, indicated in the Bulletin of the Institution of Mining and Metallurgy of England in September 1947 that he had found bauxite deposits on the banks of the Mae Klong river between Kanchanaburi and Ta Muang, but that such bauxite deposits have never been observed by the Royal Department of Mines, the two authors of this paper were detailed out to check that area.

Communications

The trip from Bangkok to Kanchanaburi can be done in one day, by train from Dhonburi to Ban Pong railway station and then by car to Kanchanaburi. It needs only 6 - 7 hours from Bangkok to Kanchanaburi. The writers left on April 22, 1948 and returned on the 24th of that month.

Method of investigation

Research was carried out by ferry boat from Kanchanaburi to Ta Muang, looking along the way for alleged bauxite occurrences. This trip took 6 hours.

Geology

To the south of the Mae Klong river, from Kanchanaburi to Muang Chum, there are limestone ranges. The strike is N-W, dip 30°SW.

On the northern bank of the river there is a quartzite range, with a strike nearly parallel to that of the limestones.

The Mae Klong river flows in an alluvial plain between two mountain ranges. This alluvial plain must have been formed by the river cutting along the contact plane of the limestone and quartzite formations, thus changing the shape of the V-valley to a flat-floored valley, which is its aspect in the present day.

/ The alluvial

The alluvial sediments consist of loose red soil, 20-30 feet thick, overlying greyish-brown silty clay which contains some slight iron stain, and the depth of which is not known.

In the hot season, from February to April, the river is at low-level stage. It was fortunate that the authors carried out their investigations in April, for nearly all the exposures along the banks are at the water level.

At some places, the banks of this river are high and steep; from Kanchanaburi to Ban Ta-lo, the banks are gently sloped and low, but from Ta-lo to Ta Muang they are steep and more than 30 feet high. At Ta Muang they are 40 feet high.

Mineral deposits

Mr. Richardson mentioned in his paper that there were two bauxite deposits along the banks of the river.

The first place is 5-6 miles downstream from Kanchanaburi; the other place is at Ta Muang. He states that those deposits had been accumulated by alluvial sedimentation. The bauxite layer is at least 6 feet thick and lies 40-50 feet underneath the ground surface. He mentioned that "The clay bed is crowded with raggy and irregularly shaped nodular concretions of pale grey and dirty-white bauxite. They are extremely rough and hackly hard, resistant, pitted and porous; their edges are sharp and cutting". He explains the origin of the bauxite as due to desilication by leaching "in situ" of silty clay.

The result of our investigations is that there is no exposure from Kanchanaburi to Ban Ta-lo, only a small outcrop at the water level at Ban Ta-lo. From Ta-lo to Ta Muang the exposures on both sides of the river are scattered. (Samples or these outcrops were collected).

/ The physical

The physical appearance of the ore body is identical to the description given by Mr. Richardson, but tests revealed that it is not bauxite ore, but a layer of calcareous nodules. The largest deposit was found between Ban Ta Mai Luak and Ta Muang; in this area it also consists of calcareous nodules and is 6-10 feet thick.

The conclusion of this report is that there is no bauxite deposit, but only calcareous nodules, a type of deposit commonly found in alluvial plain in limestone areas.

Analysis carried out at the Chemical Laboratory of the Mines Department (8 May 1948):

Al_2O_3 : 3,7%